

### **M.5.3.3 Direct Disposition Alternative for a Deep Borehole Complex**

Studies of evaluation basis accidents and beyond evaluation basis accidents have been performed for a deep borehole disposal facility and the direct emplacement of Pu and Plutonium Dioxide in the *Fissile Material Disposition Program Deep Borehole Disposal Facility PEIS Data Input Report for Direct Disposal—Direct Disposal of Plutonium/Plutonium Dioxide in Compound Canisters*. The studies postulated a set of accident scenarios that were representative of the risks and consequences for workers and the public that can be expected if the facility were constructed and operated. Although not all potential accidents were addressed, those that were postulated have consequences and risks that are expected to envelop the consequences and risks of an operating facility. In this manner, no other credible accidents with an expected frequency of occurrence larger than  $1.0 \times 10^{-7}/\text{yr}$  are anticipated that will have consequences and risks larger than those described in this section.

#### **M.5.3.3.1 Accident Scenarios and Source Terms**

A wide range of hazardous conditions and potential accidents were identified as candidates to represent the risks to workers and the public of operating the facility. Through a screening process, seven evaluation basis accidents with release to the environment and three beyond evaluation basis accidents were selected for further definition and analysis. Descriptive information on these accidents is provided in Tables M.5.3.3.1–1 and M.5.3.3.1–2. Accident source term information is provided in Tables M.5.3.3.1–3 and M.5.3.3.1–4. Descriptions of accident scenarios are provided in Table M.5.3.3.1–5.

**Table M.5.3.3.1-1. Evaluation Basis Accident Scenarios for Direct Disposition at the Deep Borehole Complex**

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Evaluation basis earthquake	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	NA	No release
Evaluation basis tornado	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	NA	No release
Evaluation basis flood	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	NA	No release
Pu storage container breakage during storage	$1.0 \times 10^{-4}$ to 0.01	$4.5 \text{ kg Pu}$	$4.5 \times 10^{-10} \text{ g Pu}$
Pu storage container breakage during handling	$1.0 \times 10^{-4}$ to 0.01	$4.5 \text{ kg Pu}$	$4.5 \times 10^{-8} \text{ g Pu}$
Emplacement canister dropped during handling	$1.0 \times 10^{-4}$ to 0.01	$40.5 \text{ kg Pu}$	No release
Onsite emplacement canister transportation accident	$1.0 \times 10^{-4}$ to 0.01	$40.5 \text{ kg Pu}$	No release
Nuclear Criticality during emplacement canister filling	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1.0 \times 10^{19} \text{ prompt fissions in 8 hrs; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.}$	<sup>a</sup> $4.05 \times 10^{-5} \text{ g Pu}$
Nuclear Criticality during Pu storage container spill	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1.0 \times 10^{19} \text{ prompt fissions in 8 hrs; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.}$	<sup>a</sup> $4.05 \times 10^{-5} \text{ g Pu}$
Fire in facility process areas	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$40.5 \text{ kg Pu}$	No release
Failure of ventilation filter	0.01 to 0.1	NA	No release
Failure of ventilation blower	0.5	NA	No release
Loss of electrical power	1.0	NA	No release
Canister string dropped during emplacement—ruptured in emplacement zone	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1,012 \text{ kg Pu}$	$4.05 \times 10^{-4} \text{ g Pu}$
Canister string dropped during emplacement—ruptured and stuck in isolation zone	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1,012 \text{ kg Pu}$	$2.43 \times 10^{-7} \text{ g Pu}$
Canister string struck in emplacement zone	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1,012 \text{ kg Pu}$	No release
Canister string struck in isolation zone	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1,012 \text{ kg Pu}$	No release
Emplacement facility fire - electrical	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1,012 \text{ kg Pu}$	No release

<sup>a</sup> See Table M.5.3.3.1-3.

Note: NA=not applicable.

Source: LLNL 1996a.

**Table M.5.3.3.1-2. Beyond Evaluation Basis Accident Scenarios for Direct Disposition  
at the Deep Borehole Complex**

<b>Accident Scenario</b>	<b>Accident Frequency (per year)</b>	<b>Source Term at Risk</b>	<b>Source Term Released to Environment</b>
Uncontrolled chemical reaction	$<1.0 \times 10^{-6}$	NA	No release
Pu container nuclear criticality in storage	$<1.0 \times 10^{-6}$	$1.0 \times 10^{19}$ prompt fissions in 8 hr; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.	<sup>a</sup>
Emplacement canister nuclear criticality in storage	$<1.0 \times 10^{-6}$	$1.0 \times 10^{19}$ prompt fissions in 8 hr; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.	<sup>a</sup>
Nuclear criticality of canister contents at bottom of emplacement zone upon rupture of dropped canister string	$<1.0 \times 10^{-6}$	$1.0 \times 10^{19}$ prompt fissions in 8 hr; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.	<sup>a</sup>

<sup>a</sup> See Table M.5.3.1-4.

Note: NA=not applicable.

Source: LLNL 1996a.

Table M.5.3.3.1-3. Direct Disposition at the Deep Borehole Complex Evaluation Basis Accident Source Terms

Accident Parameter	Frequency of occurrence <sup>b</sup> (per year)	Accident Scenario					
		Pu Storage Container Breakage During Storage	Pu Storage Container Breakage During Handling	Nuclear Criticality During Emplacement	Canister Container Filling <sup>a</sup>	Fire in Facility Process Area	Ruptured in Emplacement Zone
Pu released to environment (g)	4.5x10 <sup>-10</sup>	4.5x10 <sup>-8</sup>	—	1.0x10 <sup>-19</sup>	—	4.05x10 <sup>-5</sup>	4.05x10 <sup>-4</sup>
Fissions	—	—	—	1.0x10 <sup>-19</sup>	—	—	2.43x10 <sup>-7</sup>
<b>Isotope Released to Environment</b>		<b>Canister String Dropped During Emplacement— Ruptured and Stuck in Isolation Zone</b>					
(Ci)							
Pu-238	7.11x10 <sup>-13</sup>	7.11x10 <sup>-11</sup>	0	0	6.40x10 <sup>-8</sup>	6.40x10 <sup>-7</sup>	3.84x10 <sup>-10</sup>
Pu-239	2.57x10 <sup>-11</sup>	2.57x10 <sup>-9</sup>	0	0	2.32x10 <sup>-6</sup>	2.32x10 <sup>-5</sup>	1.39x10 <sup>-8</sup>
Pu-240	6.84x10 <sup>-12</sup>	6.84x10 <sup>-10</sup>	0	0	6.16x10 <sup>-7</sup>	6.16x10 <sup>-6</sup>	3.69x10 <sup>-9</sup>
Pu-241	2.43x10 <sup>-11</sup>	2.43x10 <sup>-9</sup>	0	0	2.18x10 <sup>-6</sup>	2.18x10 <sup>-5</sup>	1.31x10 <sup>-8</sup>
Pu-242	1.00x10 <sup>-15</sup>	1.00x10 <sup>-13</sup>	0	0	9.03x10 <sup>-11</sup>	9.03x10 <sup>-10</sup>	5.42x10 <sup>-13</sup>
Am-241	1.28x10 <sup>-13</sup>	1.28x10 <sup>-11</sup>	0	0	1.15x10 <sup>-8</sup>	1.15x10 <sup>-7</sup>	6.90x10 <sup>-11</sup>
Kr-83m	0	0	110	110	0	0	0
Kr-85m	0	0	71	71	0	0	0
Kr-85	0	0	8.1x10 <sup>-4</sup>	8.1x10 <sup>-4</sup>	0	0	0
Kr-87	0	0	430	430	0	0	0
Kr-88	0	0	230	230	0	0	0
Kr-89	0	0	1.3x10 <sup>-4</sup>	1.3x10 <sup>-4</sup>	0	0	0
Xe-131m	0	0	0.1	0.1	0	0	0
Xe-133m	0	0	2.2	2.2	0	0	0
Xe-133	0	0	27	27	0	0	0
Xe-135m	0	0	3.3x10 <sup>3</sup>	3.3x10 <sup>3</sup>	0	0	0
Xe-135	0	0	410	410	0	0	0
Xe-137	0	0	4.9x10 <sup>4</sup>	4.9x10 <sup>4</sup>	0	0	0
Xe-138	0	0	1.1x10 <sup>4</sup>	1.1x10 <sup>4</sup>	0	0	0
I-131	0	0	2.75	2.75	0	0	0
I-132	0	0	300	300	0	0	0
I-133	0	0	40	40	0	0	0
I-134	0	0	1.08x10 <sup>3</sup>	1.08x10 <sup>3</sup>	0	0	0
I-135	0	0	113	113	0	0	0

<sup>a</sup> Curies produced (by isotope) for the 1.0x10<sup>19</sup> fission criticality were scaled from Table M.5.3.1-3.<sup>b</sup> Midpoint of the estimated frequency range.

Source: Derived from Tables M.5.1.3-4-1, M.5.3.1-1-3, and M.5.3.3.1-1.

**Table M.5.3.3.1-4. Direct Disposition at the Deep Borehole Complex Beyond Evaluation Basis Accident Source Terms**

Accident Parameter	Accident Scenario			
	Pu Container Nuclear Criticality in Storage <sup>a</sup>	Emplacement Canister Nuclear Criticality in Storage <sup>a</sup>	Nuclear Criticality at Bottom of Emplacement Zone	Criticality of Canister Contents Upon Rupture of Dropped Canister String <sup>a</sup>
Frequency of occurrence (per year)	$1.0 \times 10^{-6}$	$1.0 \times 10^{-6}$		$1.0 \times 10^{-6}$
Pu released to environment	NA	NA		NA
Fissions	$1.0 \times 10^{19}$	$1.0 \times 10^{19}$		$1.0 \times 10^{19}$
<b>Isotope Released to Environment (Ci)</b>				
[Text deleted.]				
Kr-83m	110	110		110
Kr-85m	71	71		71
Kr-85	$8.1 \times 10^{-4}$	$8.1 \times 10^{-4}$		$8.1 \times 10^{-4}$
Kr-87	430	430		430
Kr-88	230	230		230
Kr-89	$1.3 \times 10^{-4}$	$1.3 \times 10^{-4}$		$1.3 \times 10^{-4}$
Xe-131m	0.1	0.1		0.1
Xe-133m	2.2	2.2		2.2
Xe-133	27	27		27
Xe-135m	$3.3 \times 10^3$	$3.3 \times 10^3$		$3.3 \times 10^3$
Xe-135	410	410		410
Xe-137	$4.9 \times 10^4$	$4.9 \times 10^4$		$4.9 \times 10^4$
Xe-138	$1.1 \times 10^4$	$1.1 \times 10^4$		$1.1 \times 10^4$
I-131	2.75	2.75		2.75
I-132	300	300		300
I-133	40	40		40
I-134	$1.08 \times 10^3$	$1.08 \times 10^3$		$1.08 \times 10^3$
I-135	113	113		113

<sup>a</sup> Curies produced (by isotope) for the  $1.0 \times 10^{19}$  fission criticality were scaled from Table M.5.3.1.1-3.

Note: NA=not applicable.

Source: Derived from Tables M.5.1.3.4-1, M.5.3.1.1-3, and M.5.3.3.1-2.

**Table M.5.3.3.1-5. Accident Scenario Descriptions for Direct Disposition at the Deep Borehole Complex**

Accident Scenario	Accident Description
<b>Evaluation Basis Accidents</b>	
Pu storage container breakage during storage	It is postulated that a Pu storage container is ruptured due to overpressurization of the container. The overpressurization could occur as a result of volume expansion caused by either complete oxidation of Pu metal buttons stored in cans or pressure buildup due to radiolysis of residual moisture in Pu oxide and helium gas from the alpha decay of Pu and daughter products. Respirable Pu fines are released to the storage area.
Pu storage container breakage during handling	It is postulated that a 2R Pu container is dropped and breaches in container handling operations. The force of the drop ruptures the container and respirable oxide fines are released to the process area.
Nuclear criticality during emplacement canister filling	Mishandling of the Pu containers during handling operations could lead to a criticality accident. At least three independent and concurrent equipment failures or operation errors must occur before a criticality accident could occur. It is postulated that additional Pu containers are introduced into the emplacement canister filling process area in violation of procedural controls and a criticality occurs as a result of the containers being spaced too closely.
Nuclear criticality during Pu storage canister spill	A nuclear criticality could occur if Pu containers were damaged in handling and the mass of the spilled Pu oxide containers exceeds the critical mass. Because each 2R primary container contains a limited amount of Pu, a criticality accident would require successively damaging several containers.
Fire in process area	The combustible loading in the process area is very low because the process does not involve any combustible materials. However, it is postulated that a large fire occurs in the process area for emplacement canister filling, the containers are breached by the fire, and the contents are exposed to the fire. The ventilation system two-stage HEPA filters are operational during the fire.
Canister string dropped during emplacement, ruptured in emplacement zone	A canister string could be dropped into the borehole as a result of either a structural failure in the crane and associated hoisting and securing equipment or as a result of operator error. A free-falling canister string could rupture upon impact at the bottom of the borehole.
Canister string dropped during emplacement, ruptured and stuck in isolation zone	A canister string could be dropped into the borehole as a result of either a structural failure in the crane and associated hoisting and securing equipment or as a result of operator error. The canister string impacts a projecting ledge at a change in the diameter of the well casings, ruptures, and remains stuck in the isolation zone instead of falling to the bottom of the borehole.
<b>Beyond Evaluation Basis Accidents</b>	
Pu container nuclear criticality in storage	The Pu storage facility is designed to ensure that an accidental criticality during dry or flood conditions is not credible. The assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.
Emplacement canister nuclear criticality in storage	The storage racks are designed to maintain the geometry of the array under all postulated accident and natural conditions. The assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.
Nuclear criticality of canister contents at bottom of emplacement zone upon rupture of dropped canister string	A canister string could be dropped into the borehole as a result of either a structural failure in the crane and associated hoisting and securing equipment or as a result of operator error. A free-falling canister string could rupture upon impact at the bottom of the borehole. The evaluation assumed that Pu released from the ruptured string would collect in a critical mass at the bottom of the borehole. The assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.

Source: LLNL 1996a.

**M.5.3.3.2      Accident Impacts**

The estimated range of impacts of the postulated accidents at reference sites is provided in Table M.5.3.3.2–1. The estimated range of environmental data (wet to dry site) and the general public population density data (low to high density) for the reference sites envelope the site characteristics expected for the direct disposition site. The dose and cancer fatality estimates are based on the analysis of the accident source terms in Tables M.5.3.3.1–3 and M.5.3.3.1–4 using the MACCS computer code. [Text deleted.]

[Text deleted.]

**Table M.5.3.3.2-1. Direct Disposition at the Deep Borehole Complex Accident Impacts Ranges at Generic Sites**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person·rem)	Number of Cancer Fatalities <sup>b</sup>
		High	Low	High	Low	High
Pu storage container breakage during storage	1.3x10 <sup>-10</sup>	5.3x10 <sup>-11</sup>	5.1x10 <sup>-14</sup>	2.1x10 <sup>-14</sup>	1.0x10 <sup>-13</sup>	1.0x10 <sup>-12</sup>
Pu storage container breakage during handling	1.3x10 <sup>-8</sup>	5.3x10 <sup>-9</sup>	5.1x10 <sup>-12</sup>	2.1x10 <sup>-12</sup>	9.4x10 <sup>-11</sup>	9.0x10 <sup>-10</sup>
Nuclear criticality during emplacement canister filling	3.5x10 <sup>-2</sup>	1.6x10 <sup>-2</sup>	1.4x10 <sup>-5</sup>	6.2x10 <sup>-6</sup>	5.8x10 <sup>-3</sup>	2.0x10 <sup>-4</sup>
Nuclear criticality during Pu storage canister spill	3.5x10 <sup>-2</sup>	1.6x10 <sup>-2</sup>	1.4x10 <sup>-5</sup>	6.2x10 <sup>-6</sup>	5.8x10 <sup>-3</sup>	2.0x10 <sup>-4</sup>
Fire in process area	1.2x10 <sup>-5</sup>	4.7x10 <sup>-6</sup>	4.6x10 <sup>-9</sup>	1.9x10 <sup>-9</sup>	8.4x10 <sup>-8</sup>	9.3x10 <sup>-10</sup>
Canister string dropped during emplacement, ruptured in emplacement zone	1.2x10 <sup>-4</sup>	4.7x10 <sup>-5</sup>	4.6x10 <sup>-8</sup>	1.9x10 <sup>-8</sup>	8.5x10 <sup>-7</sup>	9.3x10 <sup>-9</sup>
Canister string dropped during emplacement, ruptured in isolation zone	6.9x10 <sup>-8</sup>	2.8x10 <sup>-8</sup>	2.8x10 <sup>-11</sup>	1.1x10 <sup>-11</sup>	1.1x10 <sup>-8</sup>	5.0x10 <sup>-10</sup>
Pu container nuclear criticality in storage	3.5x10 <sup>-2</sup>	1.6x10 <sup>-2</sup>	1.4x10 <sup>-5</sup>	6.2x10 <sup>-6</sup>	5.8x10 <sup>-3</sup>	2.0x10 <sup>-4</sup>
Emplacement canister nuclear criticality in storage	3.5x10 <sup>-2</sup>	1.6x10 <sup>-2</sup>	1.4x10 <sup>-5</sup>	6.2x10 <sup>-6</sup>	5.8x10 <sup>-3</sup>	2.0x10 <sup>-4</sup>
Nuclear criticality of canister contents at bottom of emplacement zone upon rupture of dropped canister string	3.5x10 <sup>-2</sup>	1.6x10 <sup>-2</sup>	1.4x10 <sup>-5</sup>	6.2x10 <sup>-6</sup>	5.8x10 <sup>-3</sup>	2.0x10 <sup>-4</sup>

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Source: Calculated using the source terms in Tables M.5.3.3.1-3 and M.5.3.3.1-4 and the MACCS computer code.